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TECHNICAL REPORT

Animal Effects from Soviet Atmospheric Nuclear Tests

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ABSTRACT

This two-part document, originally titled "Historical Analysis of Atmospheric Nuclear Explosion Effects on Experimental Animals during Early Nuclear Tests, Part One and Part Two" (V.A. Logachev and L.A. Mikhalikhina, Sarov; Moscow, 1996), describes the effects on animal models of atmospheric nuclear weapons tests performed by the Soviet Union at the Semipalatinsk Test Site. Part 1 describes the air blast and thermal radiation effects. Part 2 covers the effects of primary (prompt) radiation and secondary (fallout) radiation on the test subjects. It also covers combined radiation injuries, defined as a combination of radiation and non-radiation injuries. Several different animal species were used. Animals were emplaced at varying distances from the explosion's epicenter, and in a variety of terrain configurations (open ground, trenches oriented parallel and perpendicular to the blast, etc.) The protective effects of shielding from different military vehicles and buildings were also studied. The types, degrees of severity, and clinical course of illness from the injuries produced were carefully studied in order to better understand the pathogenic mechanisms of injury and the likelihood of efficacy of proposed treatment measures. This document also covers special organ effects such as flash blindness and retinal burns. Even though these data are now over fifty years old, many of the conclusions derived from their analysis are useful today in terms of protecting humans from injury and affording good medical treatment of injuries incurred from detonation of a nuclear weapon or device.

Historical Analysis of Atmospheric Nuclear Explosion Effects on Experimental Animals during Early Nuclear Tests

Part One and Part Two

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Sarov; Moscow
1996

Only one ground surface burst of a high-yield device was produced. It was conducted on August 12, 1953 with a yield of 400 kt [12]. After this shot, lethality of animals on the ground surface was observed within a radius of 2,000 m. The boundary of the light injury zone was about 3,200 m from the epicenter.

Table 2: Blast effects from ground surface explosions of various yields on experimental animals on the ground surface.

Distance, m	Low Yield[1]							Medium Yield							High Yield						
	ΔP_f[2] MPa	Number of Animals						ΔP_f MPa	Number of Animals						ΔP_f MPa	Number of Animals					
		Total	Killed	Injury level[3]			Un-injured		Total	Killed	Injury level			Un-injured		Total	Killed	Injury level			Un-injured
				III	II	I					III	II	I					III	II	I	
75-400	30-10.7	47	43	4	0	0		-	-	-	-	-	-		-	-	-	-	-	-	
440-700	12-7	52	9	13	20	6		30-19	12	12	0	0	0		-	-	-	-	-	-	
730-1000	6-2.8	35	0	0	4	12		17-9.4	39	17	3	4	0		110-40	6	6	0	0	0	
1050-1800	3-1.8	45	0	0	0	11		8-2.5	61	1	8	0	1		25-14	13	13	0	0	0	
1900-4000	-	-	-	-	-	-		2-0.8	115	0	0	0	10		12-03.8	27	3	1	8	4	
4100-8000	-	-	-	-	-	-		0.5-0.3	22	0	0	0	0		3-1.6	6	0	0	0	0	
Total		179	52	17	24	29	57		249	30	11	4	11	193		52	22	1	8	4	17

Notes:

[1] The TNT equivalent was 1-10 kt for low-yield devices, 10-100 kt for medium-yield devices, and 100-1,000 kt for high-yield devices.
[2] ΔP_f = Shock wave front overpressure, MPa (1 MPa = 102,000 kgf/cm^2).
[3] Level I = light injuries, level II = medium injuries, level III = severe injuries.

Table 3: Blast effects from ground surface explosions of various yields on experimental animals in open trenches.

Distance, m	Low Yield							Medium Yield							High Yield						
	ΔP_f MPa	Number of Animals						ΔP_f MPa	Number of Animals						ΔP_f MPa	Number of Animals					
		Total	Killed	Injury level			Un-injured		Total	Killed	Injury level			Un-injured		Total	Killed	Injury level			Un-injured
				III	II	I					III	II	I					III	II	I	
75-400	30-17	30	21	4	3	1		>30	10	10	0	0	0		-	-	-	-	-	-	
440-700	12-7	24	0	6	8	4		30-19	10	8	0	0	0		-	-	-	-	-	-	
730-1000	6-2.8	28	0	0	4	9		17-9.4	206	6	0	2	0		110-40	12	12	0	0	0	
1050-1800	3-1.8	-	-	-	-	-		8-2.5	134	2	0	0	0		25-14	18	5	1	8	0	
1900-4000	-	-	-	-	-	-		2-0.8	4	0	0	0	0		12-3.8	12	2	0	0	0	
4100-8000	-	-	-	-	-	-		0.5-0.3	-	-	-	-	-		3-1.6	-	-	-	-	-	
Total		82	21	10	15	14	22		364	26	0	2	0	336		42	19	1	8	0	14

Table 4: Blast effects from ground surface explosions of various yields on experimental animals in closed engineering structures.

Distance, m	Low Yield							Medium Yield							High Yield						
	ΔP_f MPa	Number of Animals						ΔP_f MPa	Number of Animals						ΔP_f MPa	Number of Animals					
		Total	Killed	Injury level			Un-injured		Total	Killed	Injury level			Un-injured		Total	Killed	Injury level			Un-injured
				III	II	I					III	II	I					III	II	I	
75-400	30-10.7	26	7	0	0	0		>30	64	51	0	0	0		-	-	-	-	-	-	
440-700	12-7	20	0	0	1	0		30-19	137	4	1	0	0		>110	23	18	2	0	0	
730-1000	6-2.8	18	0	0	0	0		17-9.4	124	49	0	0	0		110-40	23	13	9	0	0	
1050-1800	3-1.8	-	-	-	-	-		8-2.5	127	23	0	0	0		25-14	23	9	2	0	0	
1900-4000	-	-	-	-	-	-		2-0.8	26	0	0	0	0		12-3.8	26	12	-	-	-	
4100-8000	-	-	-	-	-	-		0.5-0.3	-	-	-	-	-		3-1.6	6	0	0	0	0	
Total		64	7	0	1	0	56		478	127	1	0	0	350		101	52	13	0	0	36

Note:

The engineering structures were represented by military wood and soil shelters, dugouts, and reinforced concrete blocks for firing units.

Table 5: Blast effects from ground surface explosions of various yields on experimental animals in war materiel units.

Distance, m	Low Yield							Medium Yield							High Yield						
	ΔP_f MPa	Number of Animals						ΔP_f MPa	Number of Animals						ΔP_f MPa	Number of Animals					
		Total	Killed	Injury level			Un-injured		Total	Killed	Injury level			Un-injured		Total	Killed	Injury level			Un-injured
				III	II	I					III	II	I					III	II	I	
75-400	30-17	19	13	3	3	0		>30	17	9	0	0	0		-	-	-	-	-	-	
440-700	12-7	15	0	5	0	2		30-19	19	7	2	0	0		-	-	-	-	-	-	
730-1000	6-2.8	8	0	0	0	1		17-9.4	36	1	7	0	0		-	-	-	-	-	-	
1050-1800	3-1.8	-	-	-	-	-		8-2.5	37	0	0	4	2		25-14	10	5	2	0	0	
1900-4000	-	-	-	-	-	-		2-0.8	24	0	0	0	0		12-3.8	-	-	-	-	-	
4100-8000	-	-	-	-	-	-		0.5-0.3	-	-	-	-	-		-	-	-	-	-	-	
Total		42	13	8	3	3	15		133	17	9	4	2	101		10	5	2	0	0	3

Note:

The war materiel was represented by tanks, self-propelled artillery systems, and closed armored personnel carriers.

Table 6: Blast effects from atmospheric explosions of various yields on experimental animals on the ground surface.

Distance from the epicenter, m	Low Yield (W<10 kt; H=55-265 m)							Medium Yield (W=31-62 kt; H=270-1,050 m)							High Yield (W=200-1,800 kt; H=1,000-1,550 m)						
	ΔP_f MPa	Number of Animals						ΔP_f, MPa	Number of Animals						ΔP_f, MPa	Number of Animals					
		Total	Killed	Injury level III	Injury level II	Injury level I	Un-injured		Total	Killed	Injury level III	Injury level II	Injury level I	Un-injured		Total	Killed	Injury level III	Injury level II	Injury level I	Un-injured
50-400	10-4	74	22	4	8	7		30-11	27	25	2	0	0		-	-	-	-	-	-	
420-700	5-2	71	1	4	13	5		10-8	29	25	0	4	0		-	-	-	-	-	-	
700-1000	3-1.7	31	0	2	2	0		8-6	38	30	4	4	0		-	-	-	-	-	-	
1000-1800	1.5-1	38	0	0	0	2		7-3	99	19	22	37	17		15-5.5	8	5	1	0	0	
1800-4000	<1	4	0	0	0	0		4-1	102	0	2	29	36		12.5-3.5	51	17	17	9	2	
4000-8000	-	-	-	-	-	-		1-0.5	22	0	0	0	3		6.5-2	65	1	21	16	8	
8000-10000	-	-	-	-	-	-		-	-	-	-	-	-		3-1	41	0	0	0	0	
10600-20000	-	-	-	-	-	-		-	-	-	-	-	-		2.5-1	21	0	0	0	0	
Total		218	23	10	23	14	148		317	99	30	74	56	58		186	23	39	25	10	89

Table 7: Blast effects from atmospheric explosions of various yields on experimental animals placed in open trenches.

Distance from the epicenter, m	Low Yield (W<10 kt; H=55-265 m)							Medium Yield (W=31-62 kt; H=270-1,050 m)							High Yield (W=200-1,800 kt; H=1,000-1,550 m)						
	ΔP_f MPa	Number of Animals						ΔP_f, MPa	Number of Animals						ΔP_f, MPa	Number of Animals					
		Total	Killed	Injury level III	Injury level II	Injury level I	Un-injured		Total	Killed	Injury level III	Injury level II	Injury level I	Un-injured		Total	Killed	Injury level III	Injury level II	Injury level I	Un-injured
50-400	10-4	42	8	9	7	12		30-11	15	12	3	0	0		-	-	-	-	-	-	
420-700	5-2	33	0	3	0	2		10-8	14	3	3	0	2		>25	6	6	0	0	0	
700-1000	3-1	37	0	0	0	0		8-6	20	2	1	4	7		>15	6	6	0	0	0	
1000-1800	<1	22	0	0	0	0		7-3	20	0	0	0	0		15-5.5	34	18	8	0	0	
1800-4000	-	-	-	-	-	-		4-1	8	0	0	0	0		12.5-3.5	24	4	6	0	0	
4000-8000	-	-	-	-	-	-		-	-	-	-	-	-		6.5-2	12	0	0	0	0	
8000-10000	-	-	-	-	-	-		-	-	-	-	-	-		3-1	6	0	0	0	0	
10000-20000	-	-	-	-	-	-		-	-	-	-	-	-		-	-	-	-	-	-	
Total		134	8	12	7	14	93		77	17	7	4	9	40		88	34	14	0	0	40

Table 8: Blast effects from atmospheric explosions of various yields on experimental animals placed in closed engineering structures.

Distance from the epicenter, m	Low Yield (W<10 kt; H=55-265 m)							Medium Yield (W=31-62 kt; H=270-1,050 m)							High Yield						
	ΔP_f MPa	Number of Animals						ΔP_f, MPa	Number of Animals						ΔP_f, MPa	Number of Animals					
		Total	Killed	Injury level III	Injury level II	Injury level I	Un-injured		Total	Killed	Injury level III	Injury level II	Injury level I	Un-injured		Total	Killed	Injury level III	Injury level II	Injury level I	Un-injured
50-400	10-4	20	2	5	0	0		30-11	14	. 4	0	0	0		-	16	2	4	3	1	
400-700	5-2	36	0	0	0	0		10-8	16	0	0	0	0		>25	24	4	2	2	2	
700-1000	3-1	32	0	0	0	0		8-6	18	3	0	0	0		>15	16	-	-	-	-	
1000-1800	<1	36	1	1	0	0		7-3	34	2	0	0	0		15-5.5	12	2	3	-	1	
1800-4000	<1	4	0	0	0	0		4-1	22	1	0	0	0		12.5-3.5	20	2	0	0	0	
4000-8000	-	-	-	-	-	-		<1	2	0	0	0	0		6.5-2	7	0	0	0	0	
Total		128	3	6	0	0	119		106	10	0	0	0	96		95	10	9	5	4	67

Table 9: Blast effects from atmospheric explosions of various yields on experimental animals placed in war materiel units.

Distance from the epicenter, m	Low Yield (W<10 kt; H=55-265 m)							Medium Yield (W=31-62 kt; H=270-1,050 m)							High Yield (W=200-1,800 kt; H=1,000-1,550 m)						
	ΔP_f MPa	Number of Animals						ΔP_f, MPa	Number of Animals						ΔP_f, MPa	Number of Animals					
		Total	Killed	Injury level III	Injury level II	Injury level I	Un-injured		Total	Killed	Injury level III	Injury level II	Injury level I	Un-injured		Total	Killed	Injury level III	Injury level II	Injury level I	Un-injured
50-400	10-4	57	13	14	2	1		30-11	2	2	0	0	0		-	-	-	-	-	-	
400-700	5-2	51	0	2	1	0		10-8	14	0	4	1	7		-	-	-	-	-	-	
700-1000	3-1.7	10	0	0	0	0		8-6	26	4	2	0	0		-	-	-	-	-	-	
1000-1800	<1	10	0	0	0	0		7-3	18	1	0	0	0		15-5.5	38	0	0	0	0	
1800-4000	-	-	-	-	-	-		4-1	15	0	0	0	0		12.5-3.5	34	0	0	0	0	
4000-8000	-	-	-	-	-	-		-	-	-	-	-	3		6.5-2	30	0	0	0	0	
Total		128	13	16	3	1	95		77	7	6	1	7	56		102	0	0	0	0	0

The authors account for some of the discord in the experimental data presented in Tables 2 through 9 by imperfectness of diagnosis of contusion severity, the combined character of injuries for most animals put on the test fields, and other reasons. One of the causes for animal death was suffocation due to complete or partial crumbling of trenches that were constructed without slope revetment. In these cases the respiratory tracts of the animals were sometimes filled with soil. Animals fixed with fastening devices could not free themselves even with only a small crumbling of the soil, and were buried under ground.

It is of interest to note that during 1955-1957, when nuclear tests were distinguished with production of high-yield charge explosions, the shock wave front became the basic hazard factor. Thus, during the test of November 22, 1955, in the temporizing region located at a distance of 36 km from the explosion epicenter, a shelter collapsed on six safeguard battalion soldiers, covering them with soil. One soldier died from suffocation, while the others were contused. In the settlement of Malye Akzhary (60 km from the epicenter) a ceiling caved in, killing a girl. Forty-two persons were injured by glass fragments. This was the highest yield test conducted at the Semipalatinsk Test Site, 1.6 MT.

The next section covers the features of the injurious effects on animals from the thermal radiation from nuclear explosions.

Experimental data on the consequences of the thermal radiation effect on animals located openly on the ground, in open trenches, and in closed engineering structures during various surface explosions is given in Tables 12 through 14. From the data of these tables it follows that even open type structures (trenches, dugouts, slots) protect fairly reliably against burns from thermal radiation from a nuclear explosion. Animals placed in military equipment which was not involved in fire from inflammable material inflammation were uninjured, and therefore there are no tables with this data.

Table 12. Consequences of thermal radiation effect on experimental animals on the open ground from surface nuclear explosions of various yields.

Distance from the epicenter, m	Low Yield (W<10 kt; H = 55-265 m)								Medium Yield (W = 31-62 kt; H = 270-1,050 m)								High Yield (W = 200-1,800 kt; H = 1,000-1,500 m)							
	U (cal/cm^2)[1]	Number of Animals: Total	Killed	Injury level IV	III	II	I[2]	Un-injured	U (cal/cm^2)[1]	Number of Animals: Total	Killed	Injury level IV	III	II	I	Un-injured	U (cal/cm^2)[1]	Number of Animals: Total	Killed	Injury level IV	III	II	I	Un-injured
50-400	70-49	47	43	0	0	3	1	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
400-700	32-9	52	9	0	4	15	11[3]	13	25	12	12	0	0	0	0	0	-	-	-	-	-	-	-	-
700-1000	13-4	35	0	0	0	18	11	6	16	39	17	0	4	12	1	5	-	6	6	0	0	0	0	0
1000-1800	8-2	45	0	0	0	1	11	33	16-8	61	1	0	2	24	25	9	-	13	13	0	0	0	0	0
1800-4000	-	-	-	-	-	-	-	-	10-2	115	0	0	1	16	98	0	26-15	27	3	0	11	13	0	0
4000-8000	-	-	-	-	-	-	-	-	2-0.6	22	0	0	0	0	0	22	10-8	6	0	0	0	4	2	0
Total		179	52	0	4	37	34	52		249	30	0	7	52	62	98		52	22	0	11	17	2	0

Notes:

[1] *U - thermal pulse, cal./cm^2. For these tables the units of measurement that were used during nuclear testing are retained.*
[2] *With first-degree skin burns scorched eyelashes and hair were also observed.*
[3] *Other animals from those which were put on the test fields and survived did not suffer burns from thermal radiation.*

Table 13. Consequences of thermal radiation effects from surface nuclear explosions of various yields on experimental animals in open trenches.

Distance from the epicenter, m	Low Yield (W<10 kt; H = 55-265 m)								Medium Yield (W = 31-62 kt; H = 270-1,050 m)								High Yield (W = 200-1,800 kt; H = 1,000-1,500 m)							
	U (cal/cm^2)[1]	Number of Animals: Total	Killed	Injury level IV	III	II	I	Un-injured	U (cal/cm^2)[1]	Number of Animals: Total	Killed	Injury level IV	III	II	I	Un-injured	U (cal/cm^2)[1]	Number of Animals: Total	Killed	Injury level IV	III	II	I	Un-Injured[2]
50-400	70-49	30	21	No injuries from thermal radiation				9	-	10	10	0	0	0	0	0	-	-	-	-	-	-	-	-
400-700	32-9	24	0					24	25	10	8	0	0	0	0	2	-	-	-	-	-	-	-	-
700-1000	13-4	28	0					28	16	206	6	0	2	2	7	189	-	12	12	0	0	0	0	0
1000-1800	8-2	-	-					-	16-8	134	2	No injuries from thermal radiation				132	>26	18	5	0	0	0	0	13
1800-4000	-	-	-					-	10-2	4	0					4	26-15	12	2	0	0	0	0	10
4000-8000	-	-	-					-	2-0.6	-	-					-	10-8	-	-	-	-	-	-	-
Total		82	21	0	0	0	0	61		364	26	0	2	2	7	327		42	19	0	0	0	0	23

Notes:

[1] *U - thermal pulse, cal/cm^2. For these tables the units of measurement which were used during nuclear testing are retained.*
[2] *At high-yield explosions there were no burns from thermal radiation nor hair scorching in animals in open trenches that were brough alive to the clinic from distances of 1,250-4,000 m.*

Table 14. Consequences of thermal radiation effects from surface nuclear explosions of various yields on animals in closed engineering structures.

Distance from the epicenter, m	Low Yield (W<10 kt; H = 55-265 m)								Medium Yield (W = 31-62 kt; H = 270-1,050 m)								High Yield (W = 200-1,800 kt; H = 1,000-1,500 m)							
	U (cal/cm^2)[1]	Number of Animals: Total	Killed	Injury level IV	III	II	I	Un-injured	U (cal/cm^2)[1]	Number of Animals: Total	Killed	Injury level IV	III	II	I	Un-injured	U (cal/cm^2)[1]	Number of Animals: Total	Killed	Injury level IV	III	II	I	Un-injured[2]
50-400	70-49	26	7	No injuries from thermal radiation				19	-	-	51					13	-	-	-	-	-	-	-	-
400-700	32-9	20	0					20	25	137	4					133	-	23	18	0	4	1	0	0
700-1000	13-4	18	0					18	16	124	49					75	-	23	13	0	4	6	0	0
1000-1800	8-2	-	-					-	16-8	127	23					104	-	23	9	0	0	0	0	14
1800-4000	-	-	-					-	10-2	26	0					26	26-15	26	12	0	0	0	0	14
4000-8000	-	-	-					-	2-0.6	22	-					-	10-8	6	0	0	0	0	0	6
Total		64	7	0	0	0	0	57		478	127	0	0	0	0	351		101	52	0	8	7	0	42

Notes:

[1] *U - thermal pulse, cal/cm^2. For these tables the units of measurement which were used during nuclear testing are retained.*
[2] *At high-yield explosions second and third-degree burns of muzzle, ears, nasal alae, and eyelids were observed in surviving animals located in reinforced concrete structures with embrasures at a distance of 400-800 m.*

Table 15. Consequences of thermal radiation effects from atmospheric nuclear explosions of various yields on animals placed on the open ground.

Distance from the epicenter, m	Low Yield (W<10 kt; H = 55-265 m)								Medium Yield (W = 31-62 kt; H = 270-1,050 m)								High Yield (W = 200-1,800 kt; H = 1,000-1,500 m)							
	U (cal/cm^2)[1]	Number of Animals							U (cal/cm^2)[1]	Number of Animals							U (cal/cm^2)[1]	Number of Animals						
		Total	Killed	Injury level				Un-injured		Total	Killed	Injury level				Un-injured		Total	Killed	Injury level				Un-injured
				IV	III	II	I [2]					IV	III	II	I					IV	III	II	I	
50-400	60-30	74	22	0	15	4	25	8	-	27	25	2	0	0	0	0	-	-	-	-	-	-	-	-
400-700	30-18	71	1	0	16	35	6[3]	13	-	29	25	4	0	0	0	0	-	-	-	-	-	-	-	-
700-1000	16-7.5	31	0	0	3	13	7	8	-	38	30	3	1	0	0	4	-	-	-	-	-	-	-	-
1000-1800	10.5-3.5	38	0	0	3	18	14	3	65-17	99	19	10	69	4	0	-	100-65	8	5	1	1	0	0	1
1800-4000	4.5-1.5	4	0	0	0	1	3	0	30-0.4	102	0	0	49	24	23	6	80-20	51	17	9	22	0	1	2
4000-8000	-	-	-	-	-	-	-	-	5.5-2.0	22	0	0	0	0	15	7	60-30	65	1	4	42	14	4	0
8000-10000	-	-	-	-	-	-	-	-	1.5-0.5	-	-	-	-	-	-	-	26-12	41	0	0	1	9	6	25
10000-20000	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	18.5-5.5	21	0	0	3	4	14	0
Total		218	23	0	37	71	55	32		317[4]	99[4]	19	119	28	38	14		186	23	14	69	27	25	28

Notes:

[1] *U - thermal pulse, cal/cm^2. For these tables the units of measurement which were used during nuclear testing are retained.*
[2] *With first-degree skin burns scorched eyelashes and hair were also observed.*
[3] *Other animals from those which were put on the test fields and survived did not suffer burns from thermal radiation.*
[4] *Numbers do not add up; data entries are as in original. Note that totals of 317 and 99 match corresponding data points in Table 6.*

Table 16. Consequences of thermal radiation effects from atmospheric nuclear explosions of various yields on animals in open trenches.

Distance from the epicenter, m	Low Yield (W<10 kt; H = 55-265 m)								Medium Yield (W = 31-62 kt; H = 270-1,050 m)								High Yield (W = 200-1,800 kt; H = 1,000-1,500 m)							
	U (cal/cm^2)[1]	Number of Animals							U (cal/cm^2)[1]	Number of Animals							U (cal/cm^2)[1]	Number of Animals						
		Total	Killed	Injury level				Un-injured		Total	Killed	Injury level				Un-injured		Total	Killed	Injury level				Un-injured
				IV	III	II	I #					IV	III	II	I					IV	III	II	I	
50-400	60-30	42	8	0	11	2	6	15	-	15	12	0	3	0	0	0	-	-	-	-	-	-	-	-
400-700	30-18	33	0	0	0	4	2	27	-	14	3	0	3	2	0	6	-	6	6	0	0	0	0	0
700-1000	16-7.5	37	0	0	0	0	0	37	-	20	2	0	9	3	3	3	-	6	6	0	0	0	0	0
1000-1800	10.5-3.5	22	0	0	0	0	0	22	65-17	20	0	0	0	2	6	12	100-65	34	18	0	8	0	2	6
1800-4000	4.5-1.5	-	-	-	-	-	-	-	40-30	8	0	0	0	0	1	7	80-20	24	4	2	8	6	0	4
4000-8000	-	-	-	-	-	-	-	-	5.5-2.0	-	-	-	-	-	-	-	60-30	12	0	0	0	0	0	12
8000-10000	-	-	-	-	-	-	-	-	1.5-0.5	-	-	-	-	-	-	-	26-12	6	0	0	0	0	0	6
10000-20000	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	18.5-5.5	-	-	-	-	-	-	-
Total		134	8	0	11	6	8	101		77	17	0	15	7	10	28		88	34	2	16	6	2	28

Note:

[1] *U - thermal pulse, cal/cm^2. For these tables the units of measurement which were used during nuclear testing are retained.*

Most large-scale studies were performed on November 22, 1955 at a high-yield atmospheric explosion where 123 sheep were put on the open ground (76 sheep suffered visual organ burns) and 58 sheep in open trenches (12 sheep suffered visual organ burns). No thermal injuries of the visual organs were detected in animals placed in a large number of engineering structures (trenches, dugouts, reinforced concrete chambers, blocks of stationary fire structures, armored cowls, heavy and light type shelters), armored equipment (tanks, self-propelled artillery facilities, and armored carriers), and in various houses as well.

3.4 MILK CONTAMINATION

There were important integrated studies which allowed us to develop methods to assess the risk from contamination agricultural products and food prepared there from for various types of vegetation in the radiation-contaminated areas. It is known [35] that milk, a basic product of cattle, is the main portion (more than 80%) driving the entrance of radioactive materials into the human organism. The analysis results for various radiologically hazardous situations indicate that if milk contamination levels are known it is possible to evaluate the concentration of radionuclides in other cattle products such as milk reprocessing products, meat, meat products etc.

The main research efforts were performed in the radioactive trace as shown in Figure 5, formed on October 14, 1965 after a 1.1 kt nuclear explosion in borehole 1003. The depth of burst was 48 m [35, 36].

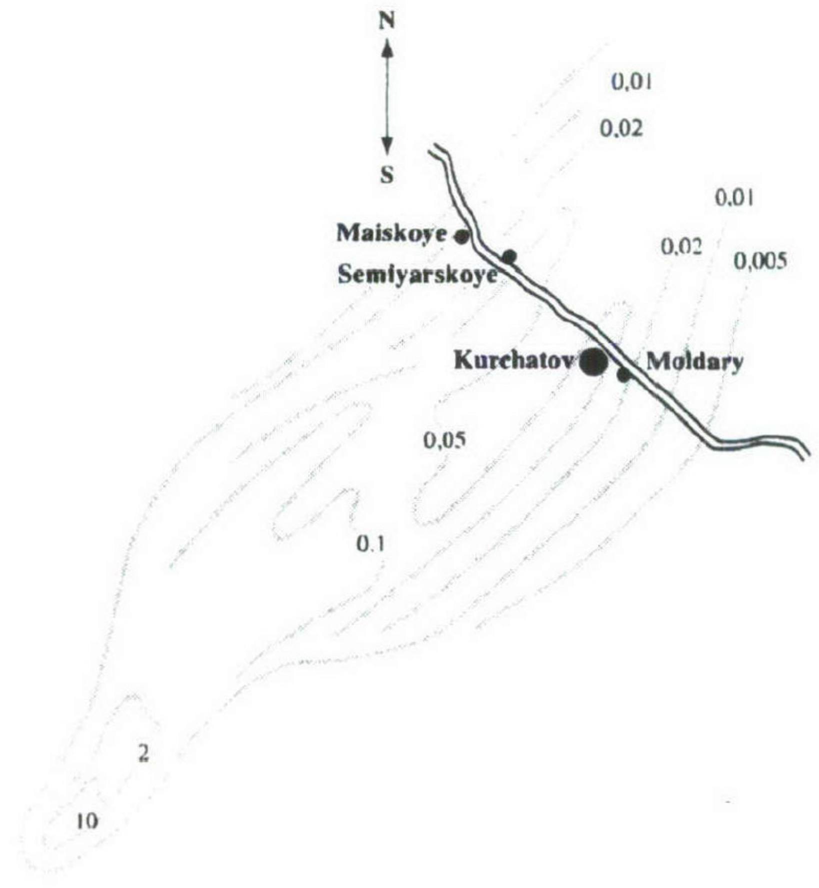

Figure 5. Schematic of radioactive trace from the underground nuclear explosion produced in borehole 1003 on 10.14.65 at Sary-Uzen area. The gamma dose rate isolines are shown in mR/hr for 24 hours after the shot.

The settlement of Moldary, which was 105 km from the explosion's epicenter, had 100 cows in lactation at the milk farm. This herd was used to study the radioactive milk evolution process.

The radiological environment at the Moldary pasture was characterized as follows: gamma dose rate was on average 0.03 mR/hr within the pasture 24 hours after the shot and the global specific activity was 87.5 kBq/kg. Table 28 contains the data on radionuclide contamination.

Table 28. Radionuclide contamination structure at the Moldary pasture.

Radionuclide	Half life	Specific activity of green grass (in Bq/kg)	Surface contamination, Bq/m^2
Strontium-89	50.5 days	$5.4 \cdot 10^3$	$8.9 \cdot 10^3$
Strontium-90	29.12 year	55.5	92.5
Zirconium-95	63.98 days	320	545
Molybdenum-99	2.75 days	$2.6 \cdot 10^3$	$4.3 \cdot 10^3$
Iodine-131	8.04 days	$2.66 \cdot 10^3$	$4.44 \cdot 10^3$
Tellurium-132	3.26 days	$5.9 \cdot 10^3$	$9.84 \cdot 10^3$
Iodine-132	20.8 hours	$3.7 \cdot 10^4$	$6.14 \cdot 10^4$
Cesium-137	30 years	91.4	152
Barium-140	12.74 days	$1.59 \cdot 10^3$	$2.64 \cdot 10^3$
Neptunium	2.35 days	$1.37 \cdot 10^4$	$2.03 \cdot 10^4$

The pasture vegetation is represented by the typical motley grass representative for this soil and climate zone of Kazakhstan. The green grass cover was on average 0.4 kg/m^2. When at pasture, the daily food ration of animals contained 50 kg of grass, 25 l of river water, and also 1.5 kg of dry mixed fodder at night time.

Cows were milked twice daily (at 7 a.m. and 6 p.m.); the average yield of milk per cow was 10 l. During the fallout period the animals were at pasture. The maintenance regime did not change after the shot.

Milk sampling for radiometry, radiochemistry, and spectrometry analysis started four hours following pasture contamination and was continued for 32 days. During this period the specific activity of milk actually decreased to background values. Milk was sampled after each milking during the first 18 days. Sampling was performed from the total bulk and the samples represented averaged samples for all cows in lactation period. The main results for milk sample measurements are given in Figure 6.

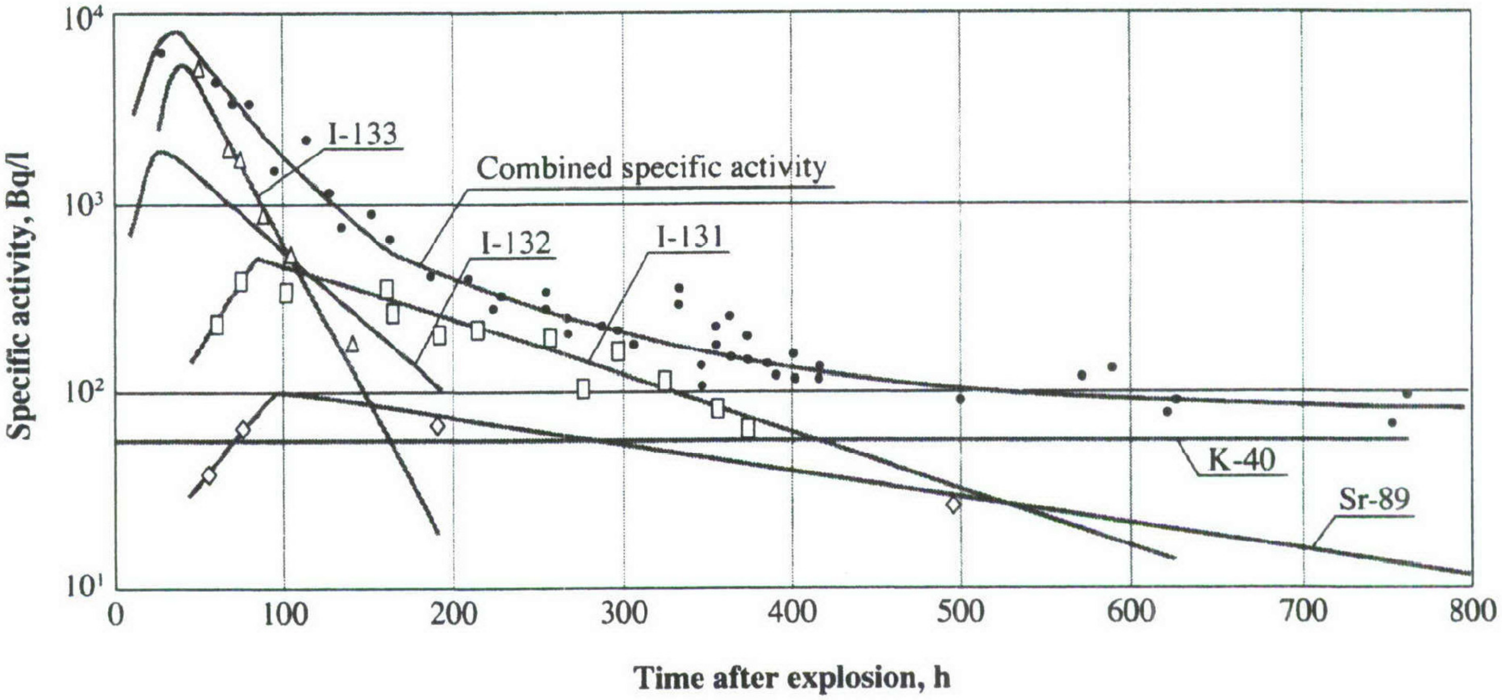

Figure 6. Time variations of specific activity in milk.

Three periods can be distinguished in the variation pattern of radionuclide concentration in milk. The first period is the increased activity in milk that lasted about 1.5 days. During this period the radionuclide concentration in milk grew very rapidly and reached 50% of the maximum value as early as four hours later. The second period demonstrated a relatively fast decrease in milk activity. For 10-11 days of this period the total milk activity decreased by 30-32 times as the short-lived iodine-133 and iodine-132 decayed. The third period involved a monotonic decrease of milk contamination to the natural background activity.

The rate of milk clearing was determined both by the physical decay of radionuclides and other (non-radiological) factors of food clearing. These factors might involve growing of new (fresh) grass and the preference the animals gave to it, as well as the features of the vegetation period. It is important to note that the milk half-clearing periods for pasture-based maintenance were shorter (two to five-fold less) than the half-lives of the corresponding radionuclides.

3.5 INHALATION RISK EVALUATION

The research into radioactive material inhalation hazards was performed with experimental animals, mainly dogs, during the entire period of atmospheric nuclear tests.

From the biological viewpoint the actual inhalation risk is only from radioactive materials residing on particles less than 50 μm in diameter. Radioactive particles of this size can enter the organism through unprotected respiration, remain on the skin and clothing, be eaten by animals together with grass, etc.

For evaluation of inhalation risk, the basic goal was to determine the ratio between quantitative

The experiments for the inhalation risk evaluation used about 50 male and female mongrel dogs with an average weight of 12.6 kg. The main conclusion of the risk evaluation experiments was that elementary protection means for the respiration organs (such as respirators) are relatively efficient and can be used in emergencies.

In addition to dogs and larger animals, the experiments for the studies of nuclear weapon injurious effects also used small laboratory animals such as rats and mice. They were extensively used to study the migration processes of nuclear explosion products and various radionuclides over the biological chains. Due respect should be given to the animals of all types, and especially to dogs, that were and still remain the main assistants in experimental research, not only in radiobiology but also in medicine in general.